Modeling Honeycomb Sandwich Composite using Polygonal Finite Element Method & Simulation of Crack Propagation using XFEM

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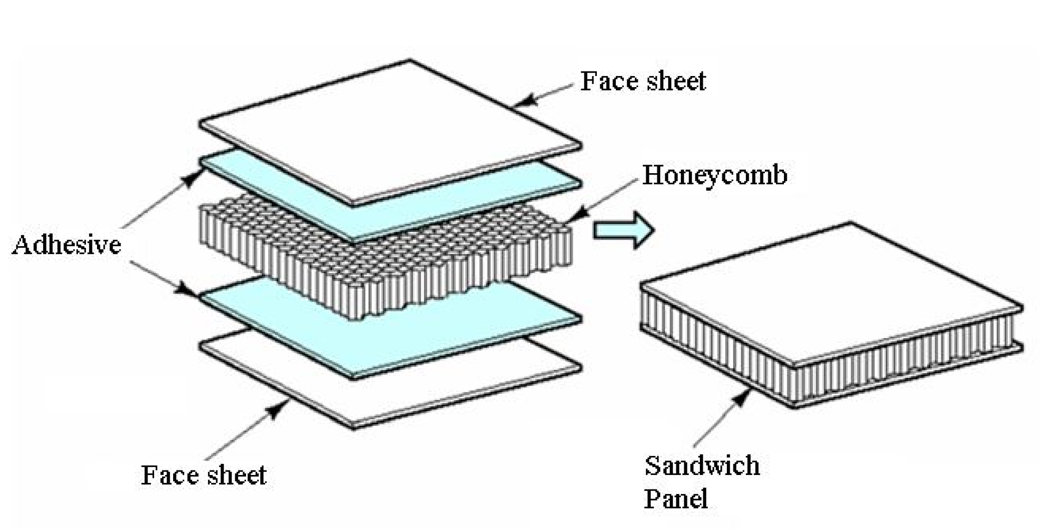
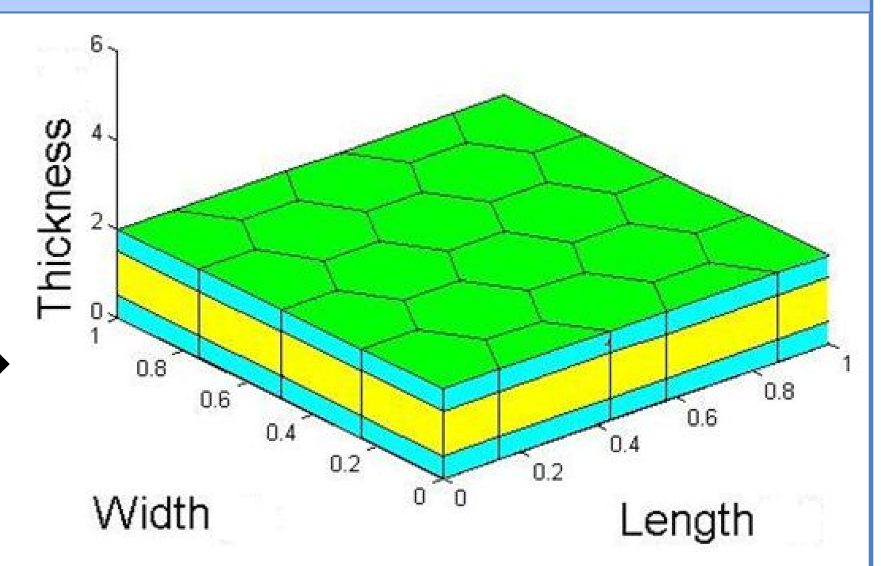
Abstract

we propose a new scheme of analyzing flexural deformation behavior of Honeycomb Sandwich Plate. In the present formulation, each of the hexagonal shaped face sheet elements modeled explicitly using single Polygonal Finite Element (PFEM). The polygonal finite elements with Wachspress basis functions are employed to study static bending of honeycomb sandwich plates. The advantage is that the cell elements are not required to be discretized further. However, the proposed basis functions on polygons are rational in nature, which poses challenges in obtaining optimal numerical integration. Several schemes have been proposed in the literature to integrate over the polygonal domains. In this paper, a new method is proposed by using Schwarz-Christoffel mapping for numerical integration and the optimal integration points have been found for bending of polygonal element. Finally, enriched interpolation scheme in this line of eXtended Finite Element (XFEM)is incorporated to analyze fracture behavior of honeycomb sandwich plate. An edge crack is modeled in the adhesive layer and crack propagation is simulated.

Honeycomb Sandwich Structure



(a) Sandwich structure and its constituents.



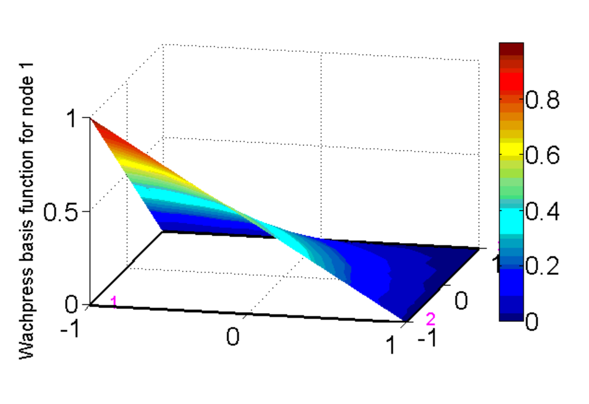
(b) Polygonal FE model of sandwich plate.

❖ A honeycomb sandwich panel consists of a hexagonal cell wall based honeycomb core sandwiched between two face sheets.

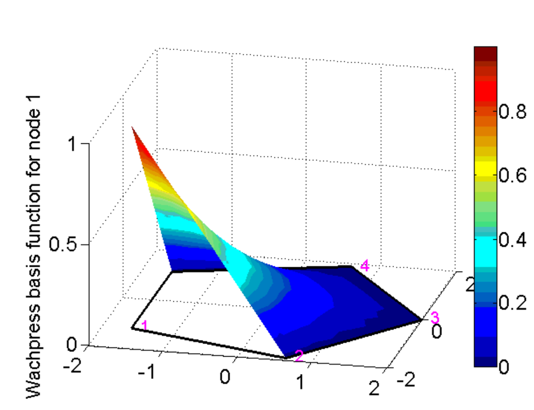
❖ Continuum models of honeycomb sandwich panel involving hexagonal shape of face sheet region bonded along its edge with the side walls of the core has been modeled using a reduced-order assembly of hexagonal face elements and rectangular wall elements.

❖ Adhesive layer is modeled explicitly in between the face sheets and the core elements.

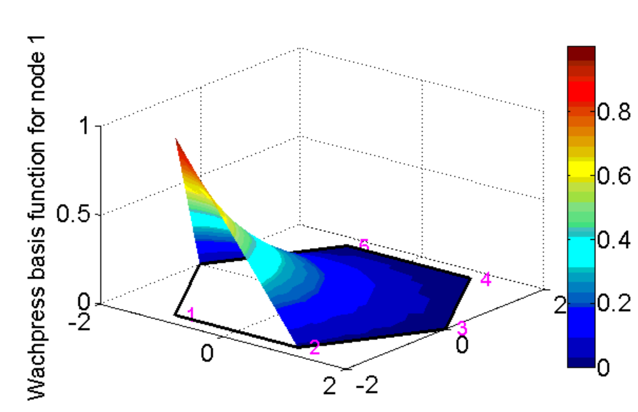
Interpolation on polygons(Wachspress Shape Functions)



(c) Quadrilateral domain.



(d) Pentagonal domain.



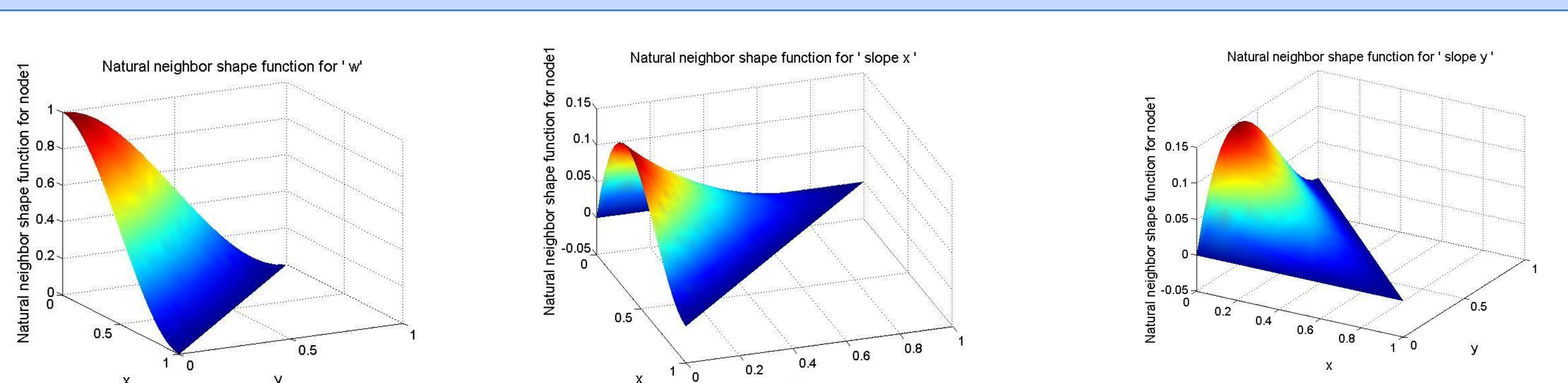
(e) Hexagonal domain.

❖ Wachspress constructed rational basis shape function on polygonal domain.

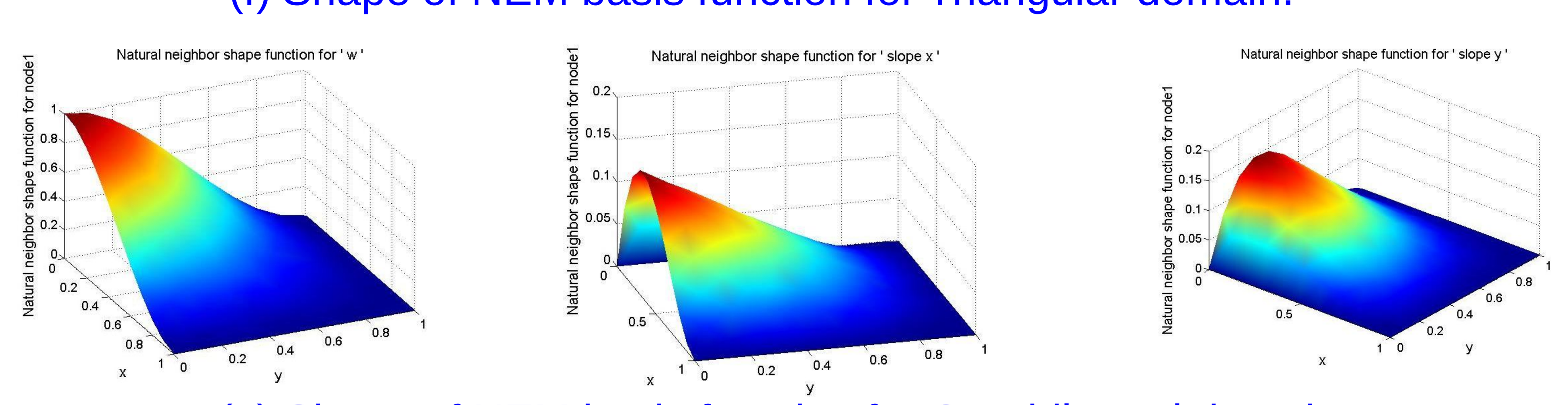
❖ Polygonal Finite Element (PFEM) has rational polynomial base displacement interpolation field at the interior and linear displacement field along the boundary.

❖ Above figure shows the shape of Wachpress basis function in polygonal domain.

Interpolation on polygons(Natural Element C^1-Shape Functions)



(f) Shape of NEM basis function for Triangular domain.



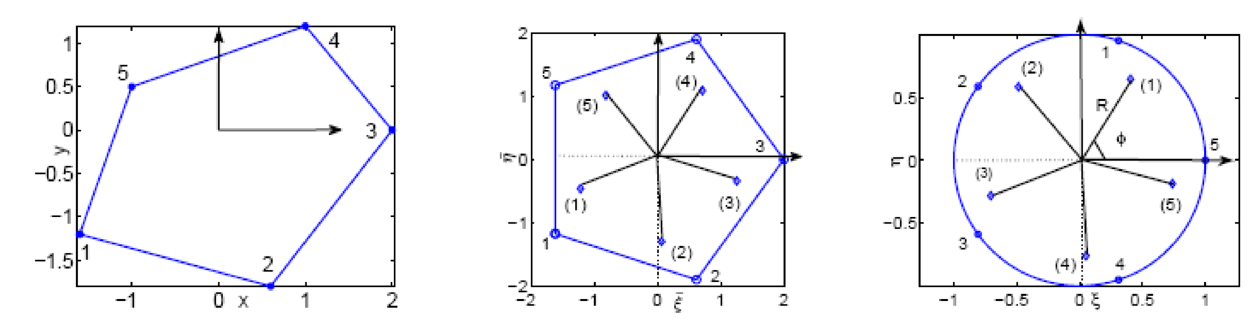
(g) Shape of NEM basis function for Quadrilateral domain.

❖Natural element C^1-shape function can be used as an interpolation scheme of polygonal elements for Kirchhoff (Thin) plate bending problem.

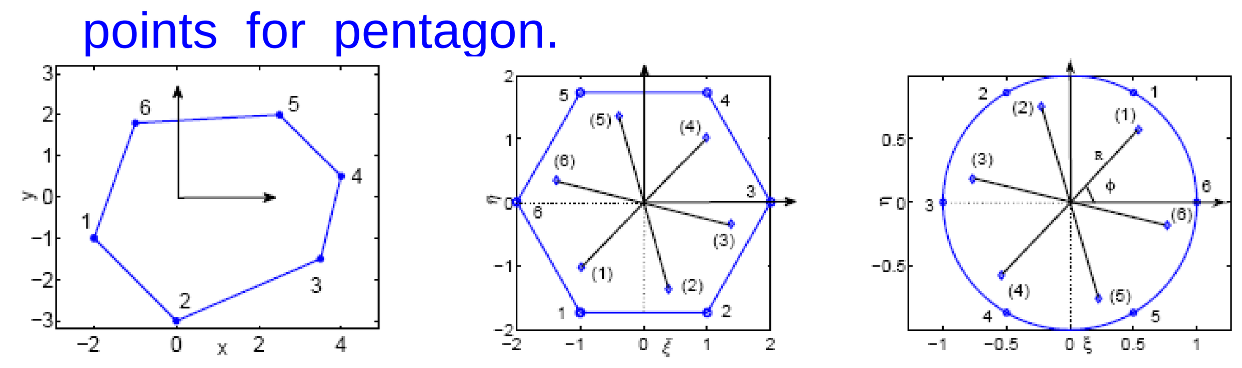
References

[1] Wachspress EL.A Rational Finite Element Basis. Academic Press: New York, NY, 1975.
[2] S.Natarajan, S.Bordas, D Roy Mahapatra: Numerical integration over arbitrary polygonal domains based on Schwarz-Christoffel conformal mapping. International Journal for Numerical Methods in Engineering, 80(2009), 103-134.
[3] N.Sukumar,A.Tabarraei:A conforming polygonal finite elements. International Journal for Numerical Methods in Engineering, 61(2004), 2045-2066.
[4] S.Chakraborty, S.Singh, S.Natarajan, D Roy Mahapatra, S.Bordas. Optimal numerical integration schemes for polygonal finite elements. (manuscript under review).

Schwarz-Christoffel Conformal Mapping



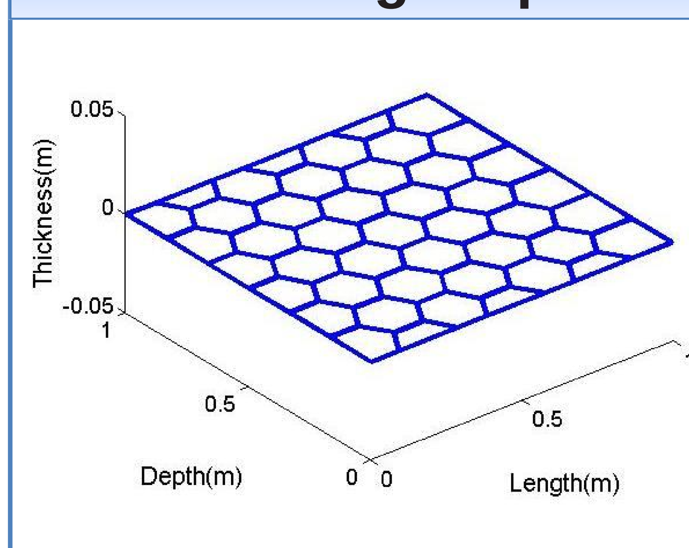
(h) Two level mapping and placement of integration points for pentagon.



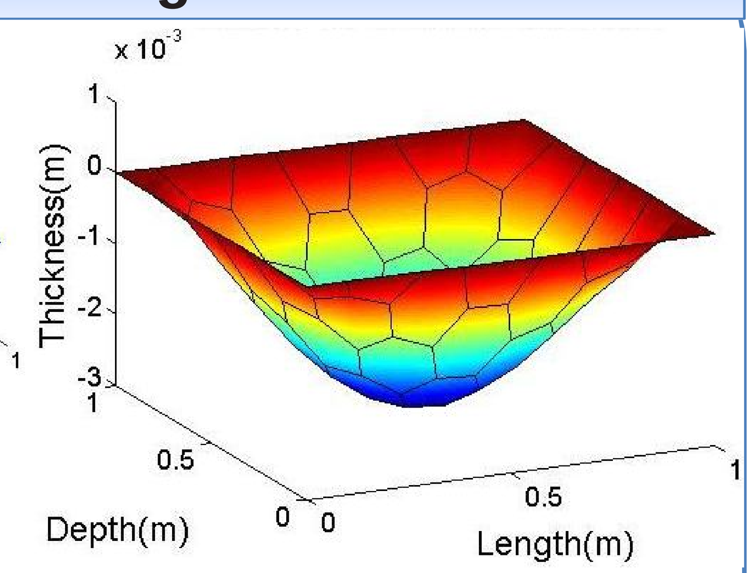
(i) Two level mapping and placement of integration points for hexagon.

❖ Optimal numerical integration points are found on the unit circle.

Plate bending response using PFEM

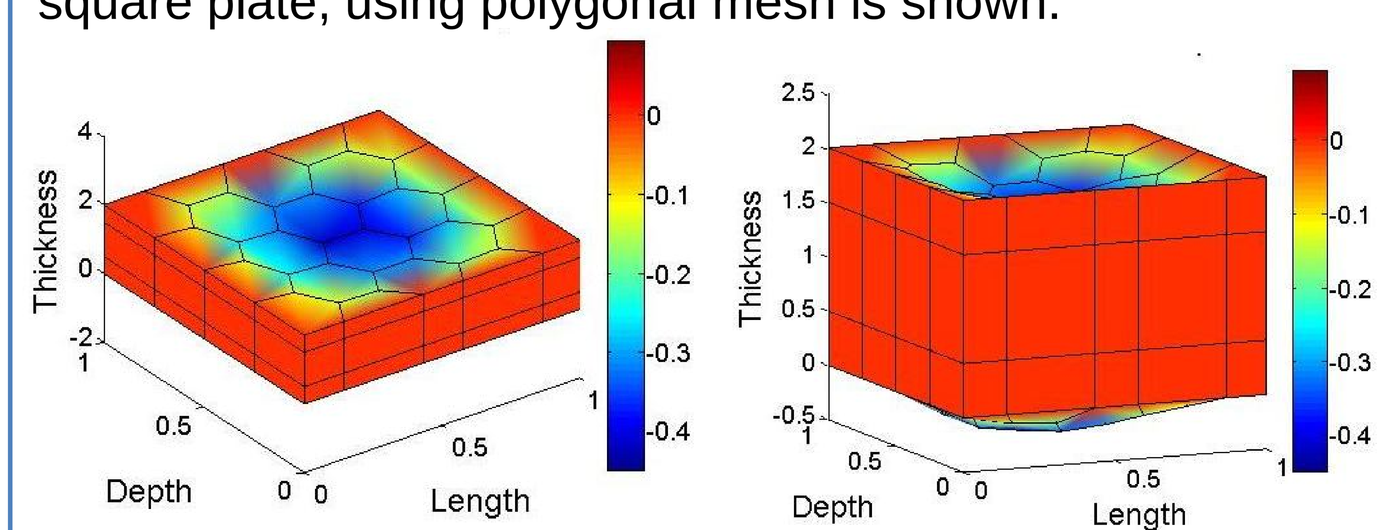


(j) Polygonal mesh



(k) Deflection plot

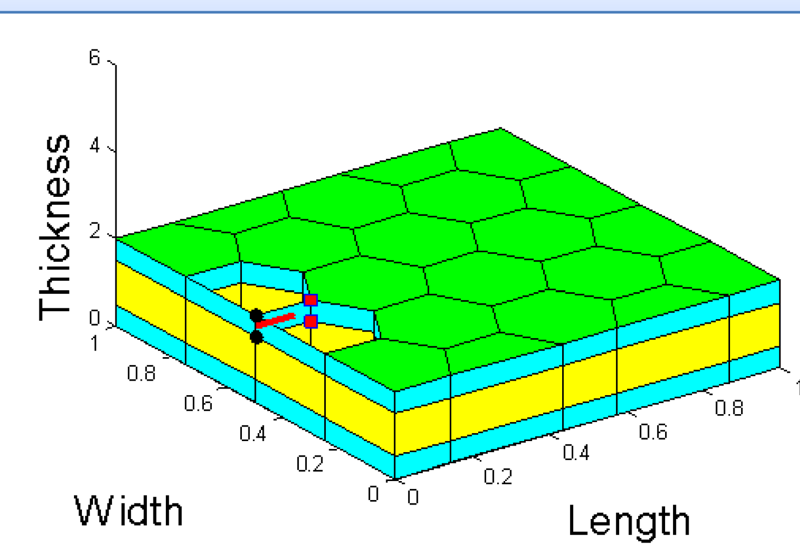
In above figure , the deformed shape of a simply-supported square plate, using polygonal mesh is shown.



(l) Deflection plot of simply supported sandwich plate

❖ The simply supported sandwich plate has been modeled as shown in figure(b) and uniform pressure loading is applied.

Ongoing work



(m) Crack modeling in sandwich plate

❖ An edge crack is modeled in the adhesive layer .

❖ An enriched interpolation framework (XFEM) is used to analyze fracture behavior of honeycomb sandwich plate and simulate the crack growth.

Improvement over Shear Locking Element

❖Shear locking is influenced primarily by the percentage contribution of element boundary w.r.t the element area.

❖ Mesh index=$\dfrac{(\Sigma \text{ Element edge length})^2}{\text{Area of the plate}}$

❖Change in bending strain energy and shear strain energy study w.r.t mesh index is carried out for quadrilateral mesh and simultaneously for polygonal mesh.

❖The center deflection of a simply supported square plate under uniform transverse pressure loading is studied w.r.t the ratio of thickness to span (t/L) of the plate for different mesh index.

❖ There is a trade off in the performance of shear locking between linear quadrilateral and polygonal elements.

Publications from this work

Simulation of crack propagation in honeycomb sandwich plate using XFEM and Polygonal FEM. Fourth International Congress on Computational Mechanics and Simulation, Hyderabad,9-12December 2012.(To appear in conference proceedings)